# SICK-BUILDING SYNDROME PROBLEMS AND HOW THEY CAN BE SOLVED

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There are more and more reported incidents of "sick" office buildings. This problem was first recognized and studied in Scandinavia in the early 1970s and has subsequently been widely studied throughout Western Europe and North America. The most common symptoms reported by occupants of sick buildings include mucous-membrane irritation, eye irritation, headaches, lethargy, fatigue, nausea, dizziness and skin rash or itchiness. These symptoms are accompanied by complaints of a lack of fresh air, stuffiness, inadequate temperature control and unpleasant odors. A building is defined to be sick when more than 20 percent of the occupants report symptoms on a regular basis.

An office building that does not achieve adequate environmental conditions can affect not only the health of occupants but also office productivity. If building occupants are satisfied with their indoor environs, the prevalence of health complaints is lower, absenteeism is decreased, and the work place is generally more productive. This has been demonstrated in one study shown, in Figure 1, of Vancouver office workers before and after their company relocated to a modern-type office building (Sterling, 1983). The graph of absenteeism demonstrates a dramatic increase related to the prevalence of health and comfort complaints after relocation. Both health and comfort problems reduced office productivity.

It has been estimated that up to 90 percent of the currently available office building stock has potential for becoming a sick building. An article in the *American Institute of Architecture Journal* warns that the single most important area of liability litigation facing architects and engineers is that of public health hazards associated with the environmental performance of buildings (LePatner, 1987). Examples of such litigation to date include materials such as asbestos and formaldehyde. Other recent examples are carpets, radon-generating components of buildings, microbial contamination of air conditioning systems and exposure to toxic construction materials during remodeling.

Fortunately, such problems can be limited. To avoid sick buildings, architects and engineers need to understand the health and comfort problems that can be created by poor building design, construction, operation and maintenance.

Table 1 provides a summary of what is now known about specific causes of sick building syndrome. The table presents the results of 529 investigations undertaken by the U.S. National Institute for Occupational Safety and Health (NIOSH, 1989) and 1362 investigations undertaken by Health and Welfare Canada (Kirkbride et al., 1990). (See Table 1, page 10.)

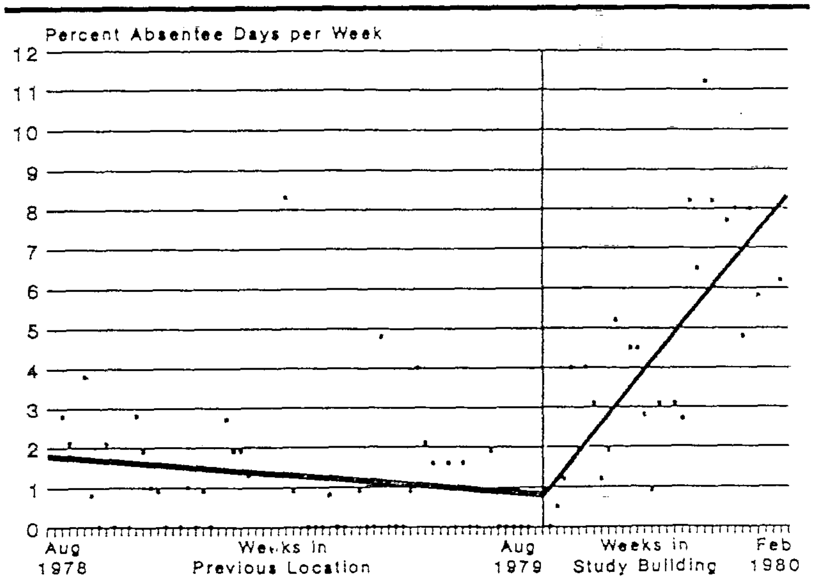
The findings of the U.S. and Canadian agencies are remarkably similar. In over 50 percent of investigated buildings, inadequate ventilation was identified as the primary cause of IAQ problems. The term "inadequate ventilation" refers to a range of HVAC-related inadequacies such as lack of outside air, poor air distribution, poor thermal control and inadequate maintenance procedures (Collett and Sterling, 1988a).

Other identified causes include contamination from specific indoor sources (12 to 15 percent of investigated buildings), infiltration of outdoor contaminants (9-10 percent), contaminants from building materials and interior furnishings (2-4 percent) and microbial contamination (1-5 percent).

An illustration of the complexity of

FIGURE 1

Absentee Rate of Office Workers Before and After Relocation

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investigating IAQ problems is the finding that the cause could not be determined by the investigators in between 13 and 24 percent of the buildings being investigated.

The experience of other researchers has been similar, with inadequate ventilation consistently having been identified as the major cause of IAQ-related problems in offices and other nonindustrial work environments (Robertson, 1988, Rask and Lane, 1989; Nathanson, 1990).

While the reported findings from NIOSH and Health and Welfare Canada provide an important insight into the causes of IAQ problems, the summary tables may oversimplify the field situation. The data in Table 1 summarizes one primary problem for each investigated building. However, our own field experience rarely identifies a single problem in a building. Typically, several inadequacies are identified within a building which contribute to occupant discomfort and ill-health.

Table 2 summarizes our research groups' findings of 85 buildings in Canada, the United States and South America. The table shows specific causes that have been identified as contributing to IAQ-related problems.

Our findings are generally similar to those of government agencies and private-sector researchers. The identified causes of IAQ-related problems can be broadly categorized into two types: design and operational inadequacies of HVAC systems and the presence of specific contaminants from a variety of sources. These two categories are not mutually exclusive. For example, the presence of elevated formaldehyde concentrations resulting from off-gassing from interior furnishings may be diluted by adequate ventilation or intensified by a lack of outside air or poor air distribution. From our experience, occupants most often complain of discomfort (e.g., too hot, too cold, stuffiness, lack of fresh air) and a series of short-term acute symptoms (headache, fatigue, mucous-membrane irritation) which are typical of the sick building syndrome, rather than chronic health impairment.

In our experience, the single most frequent cause of occupant complaint is inadequate control of the indoor environment by the mechanical ventilation system (36 percent of all identified causes). Problems of an inadequate outside air supply and poor air distribution within a space can be related to both the design and operational characteristics of the HVAC system. Design problems may be a function of the design parameters of a building with low outside air ventilation rates desired for optimum energy efficiency or minimum code requirements. Operational deficiencies include building operators' closing of outside air dampers (again for energy efficiency) inappropriate minimum damper settings (particularly in variable-air-volume systems), unbalanced air distribution systems and the presence of barriers to effective air distribution, such as partitioning of a space or occupant blocking of diffusers.

A dramatic reduction in ventilation standards may be the major reason that inadequate ventilation has been shown to be the predominant cause of sick buildings in North America. In 1975, the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) reduced the recommended level of outside air ventilation from 25 cubic feet per minute per person to 5 cubic feet per minute per person (ASHRAE 1975). 1975 is when the epidemic of sick buildings first came to the attention of public-health authorities in North America. Figure 2, a graph that relates occupant satisfaction to indoor conditions with the outside air ventilation rate, clearly demonstrates why this epidemic occurred. When outside air is reduced to 5 cfm per person the percent of satisfied occupants is less than 50 percent. When outside air is increased to 20 cfm per person, nearly 90 percent of occupants are satisfied. Increasing the ventilation rate further has little effect. As a result of occupant complaints of

Table 1

CAUSES OF IAQ PROBLEMS IN 1891 WHITE-COLLAR WORKPLACES INVESTIGATED BY NORTH AMERICAN GOVERNMENT AGENCIES

| | NIOSH 529 Buildings (1971-88) NIOSH, 1989 | | HWC 1362 Buildings (1984-89) Kirkbride, 1990 | |
|---|---|---|---|---|
| Problem Type | Number | Percent | Number | Percent |
| Inadequate Ventilation | 280 | 53 | 710 | 52 |
| Indoor Contaminants | 80 | 15 | 165 | 12 |
| Outdoor Contaminants | 53 | 10 | 125 | 9 |
| Building Fabric | 21 | 4 | 27 | 2 |
| Biological Contamination | 27 | 5 | 6 | 0.4 |
| Unknown | 68 | 13 | - 329 | 24 |

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poor ventilation, ASHRAE increased the recommended outside air ventilation rate for offices to 20 cfm per person in 1989 (ASHRAE, 1989a). (See Figure 2, page 12.)

## Solutions to the Sick-building Problem

The following sections of this article will deal with solutions to the sick building problem both in existing buildings and in the design and construction of new buildings.

### Retrofit of Existing Buildings

Ninety percent of buildings that are going to exist in the year 2000 have already been built. Many of these buildings were constructed between 1975 and 1989, and are likely to experience IAQ problems The State of Washington Department of Labor and Industries is about to implement regulations for "Indoor Air Quality in Non-Industrial Work Environments." These regulations will have a tremendous impact on buildings constructed between 1975 and 1989, precisely the population of buildings that are likely to experience IAQ problems. The regulations will require both proactive monitoring of potential IAQ problems and timely response to complaints.

The approach that Theodor D. Sterling and Associates (TDSA) Ltd. currently uses to conduct, and recommend for, IAQ evaluations consists of the following seven stages:

1. Initial assessment.
2. Assessment of health and comfort

Table 2

SPECIFIC CAUSES IDENTIFIED AS CONTRIBUTING TO IAQ-RELATED PROBLEMS IN 85 BUILDINGS

| Cause of Problem | # of Times Cause was Identified | % of Times Cause was Identified |
|---|---|---|
| Ventilation Control<br>• lack of outside air<br>• poor air distribution | 57 | 36 |
| Thermal Control<br>• inadequate capacity<br>• operational deficiencies | 30 | 19 |
| Ventilation Infiltration<br>• outside air intake location | 16 | 10 |
| Cross- contamination<br>• parking garage<br>• print shop<br>• smoking lounge | 18 | 11 |
| Indoor Sources<br>• interior furnishings<br>• fibrous insulation | 14 | 9 |
| Microbial Contamination<br>• poor maintenance<br>• water leakage | 11 | 7 |
| Site Infiltration<br>• adjacent industry<br>• underlying soil | 4 | 2 |
| Undetermined Cause | 9 | 6 |

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concerns.
3. IAQ and thermal comfort monitoring.
4. Follow-up IAQ measurements.
5. Ventilation measurements.
6. Development and implementation of mitigation strategies.
7. Post-implementation assessment.

Each of the first five stages does not necessarily have to be completed before conclusions are drawn and Stage 6 (development and implementation of mitigation strategies) is implemented. For example, if the cause of IAQ-related problems is determined at Stage 1 (initial assessment), the investigation would immediately proceed to Stage 6.

*Stage One: Initial Assessment*

Our investigations are normally instigated by a building owner, manager or tenant in response to occupant complaints of discomfort or ill-health which are suspected to be related to indoor environmental conditions.

The first stage of investigation is an initial assessment in which information about occupant concerns and the physical building are gathered from the following sources:

1. Meetings with the building operator and occupant representatives, e.g., an Occupational Safety and Health Committee or individual who coordinates complaint procedures.
2. Review of available architectural and engineering plans.
3. Walkthrough inspection to identify pollutant sources within and adjacent to the building (e.g., parking garages, print shops, kitchens); to inspect the design configuration and operational conditions of the building's heating, ventilation and air conditioning (HVAC) systems (e.g., local ions of air intakes and exhausts, presence of standing water); and to observe characteristics of the occupied space, particularly in those areas in which occupants report a high prevalence of health and comfort complaints (as determined in previous meetings).

*Stage Two: Assessment of Occupant Concerns*

Evaluation of the type and extent of reported discomfort and health may be accomplished by extensive questionnaire surveys, formal medical examination, or informal occupant interviews. Our field experience suggests that the investigative approach must be flexible, responding to the specific requirements of a particular project. A standardized questionnaire is of the greatest value in building complexes with large occupant populations. The results may be used to quantify the prevalence and type of health and comfort complaints, and also to determine the spatial distribution of complaints between and within floors. Identification of specific problem locations is important in the development of the sampling protocols used in Stages 3 and 4 (IAQ Assessment).

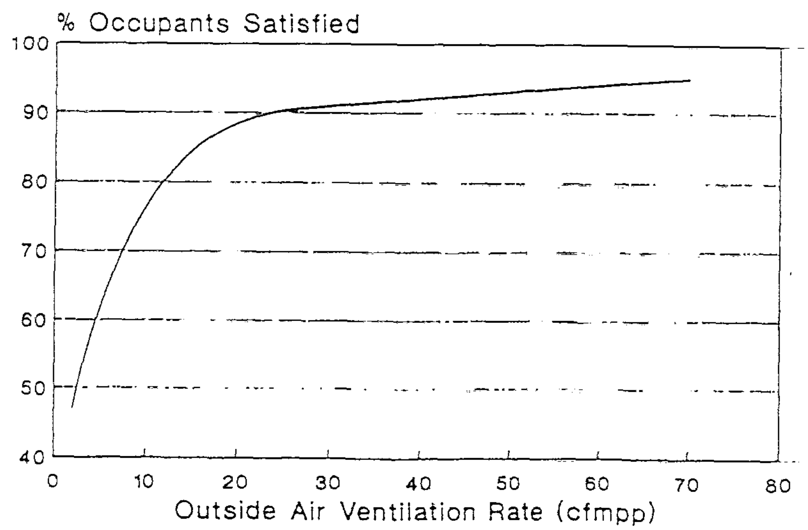
We have also used questionnaire surveys to evaluate the impact of demographic differences (age, sex) and psychosocial factors (stress, satisfactions) on the prevalence of occupant complaints (Klevin and Sterling, 1988).

In investigations of smaller workplaces, or of specific floors within larger complexes, our experience has shown direct interviews to be effective in gathering data regarding occupant concerns, either through a series of structured interviews or informal discussions during the walkthrough inspection.

Interview or examination by an occupational-health physician may be required in cases where specific and serious health impairment has been reported by occupants or diagnosed by their physicians. While this is not a common approach in "typical" building evaluations, it may be necessary in assessing a specific building-related illness in which a known etiologic agent such a microbial contaminant is suspected as the cause of the problem.

FIGURE 2

RELATIONSHIP BETWEEN VENTILATION RATE AND REPORTED OCCUPANT SATISFACTION




Source: Adapted from EEC Guidelines for Ventilation 1992

*Stage Three: IAQ and Thermal Comfort Monitoring*

The following two stages evaluate the chemical composition and thermal condition of the indoor air. In stage three, five parameters are monitored to indicate the general performance of the HVAC systems:

- carbon dioxide as an indicator of the adequacy of the outside air supply, determined with a nondispersive infrared analyzer;
- carbon monoxide as an indicator of the infiltration of combustion by-products, measured using an electrochemical analyzer;
- respirable suspended particles as an indicator of filtration effectiveness and the general dust loading of the indoor environment, determined using nephelometric monitors;
- temperature and relative humidity as indicators of thermal comforts mea-



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sured with a quick-response electronic sensor.

The direct-reading instruments are used to gather data at sampling locations throughout the study area and an outdoor site adjacent to the HVAC system air intakes. Sampling locations are selected to reflect different uses of a space, to incorporate all HVAC zones, and to investigate "problem" locations identified in the previous stages. Multiple sampling passes through each site are undertaken throughout a working day to evaluate diurnal variations. In addition to the sampling passes through a building, one or more continuous monitoring stations are set up to record trends in carbon dioxide, temperature and relative humidity. The continuous monitors are typically placed into "worst case" locations as identified in the walkthrough inspection.

- other environmental parameters that are monitored at this stage, only if a problem is suspected from the walkthrough inspection and assessment of occupant concerns, include lighting and noise levels.

*Stage Four: Follow-up IAQ Measurements*

Additional IAQ sampling may be undertaken as dictated by the findings from the previous stages, in particular, if specific point sources of indoor pollution are identified in the walkthrough inspections, or the occupants' symptomology suggests the presence of a particular contaminant. Follow-up measurements may include sampling and analysis for formaldehyde, airborne fungi and bacteria, total and specific volatile organic compounds, ozone and nicotine. Evaluation of these substances typically requires integrated sampling techniques with a known volume of indoor air drawn through a collection medium and laboratory analyses of the collected sample. The results of the monitoring conducted during Stages 3 and 4 are compared to available standards and guidelines, such as those developed by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) including Standard 62-1989: Ventilation for Acceptable Indoor Air Quality (ASHRAE; 1989a), and Standard 55-1992: Thermal Environmental Conditions for Human Occupancy (ASHRAE; 1992). Comparison is also made with IAQ consensus guidelines which identify IAQ concentrations "of concern" and "of limited or no concern" (WHO, 1984). In addition, we compare data gathered in a particular building with data from both problem and non-problem buildings archived into an in-house Building Performance Database (Collett et al., 1987).

*Stage Five: Ventilation measurements*

If inadequate HVAC system performance has been implicated as a cause of IAQ-related problems in the previous stages through comparison with existing standards and guidelmes, but has not been fully confirmed, quantification of ventilation performance parameters maybe necessary. Actions include air flow measurement to determine flows through the duct work, and supply and exhaust vents, and tracer gas evaluation to determine air exchange rates on specific floors of the overall building. Sulfur Hexaflouride ($SF_6$) has been widely used as a tracer in office buildings. Some of the published protocols for IAQ investigation suggest the use of $CO_2$ as a tracer, as a simplified, less costly method than $SF_6$ (Goyer and Nguyen, 1989). However, while $CO_2$ provides a useful general indicator of the adequacy of the outdoor air supply and IAQ, the accuracy of the use of $CO_2$ as a tracer gas may be questionable due to the difficulty of achieving the assumptions associated with the $CO_2$ method under field conditions (Levine et, al., 1992).

Tracer gas, such as $SF_6$, may also be used to investigate the patterns of air flow within a building, for example, to determine whether air from a parking garage is infiltrating other areas within a building.

*Stage Six: Development and Implementation of Mitigation Strategies*

When conclusions have been drawn from the implementation of one or more of the preceding stages and the cause(s) of the IAQ problems have been determined, retrofit actions to mitigate design-related problems and recommendations to improve operational and maintenance parameters to rectify the problems and improve indoor environmental conditions must be developed and implemented.

*Stage Seven: Post-implementation Assessment*

A final, but important, stage is follow-up assessment to determine the effectiveness of the retrofit actions. Ideally, the assessment should include objective measurement of IAQ and thermal parameters. However, detailed follow-up assessment is rarely conducted. One exception was the reevaluation of two office buildings using a Standardized questionnaire (Collett and Sterling, 1988b). In this project, IAQ problems were identified in both buildings and retrofit actions were recommended. The retrofits were completed in one build-



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ing, while changes were not implemented in the second building. Follow-up surveys of the two buildings' populations showed a significantly reduced prevalence of reported discomfort and ill-health in the retrofitted building and no change in the nonretrofitted building.

### The Design of New Buildings

We have now described an approach for investigation and mitigating of IAQ problems in existing buildings. However, an alternative approach is to design and construct a building correctly the first time. TDSA Ltd. has been involved as the environmental quality consultant for a number of recent building projects and has developed a framework for design that, if followed, will help avoid environmental problems in new buildings.

The ideal strategy is for the environmental consultants to begin working with the design team at the program and conceptual stages of a project. Energy consultants are often included at this stage. However, environmental consultants are rarely called upon until well into the design process or, more often, until the building is constructed and problems are occurring.

The environmental consultant should be brought into the project early enough to assist development of the building program and to review design decisions that could influence the ultimate livability of the building. Specifically, the environmental consultants' roles are to:

1. Formulate a program of environmental goals and objectives for the design.
2. Review the design schematics to evaluate whether the environmental objectives have been reached.
3. Inspect the building after construction and test building performance relative to the environmental objectives.

A Design Brief should be prepared by the design team which includes detailed criteria for the building requirements. An integral part of these criteria should be environmental and performance goals. These goals encompass:

- Heating, Ventilation and Air Conditioning (HVAC)
- Illumination
- Architecture
- Commissioning and Operation

#### *Heating, Ventilation and Air Conditioning*

Inadequacies of HVAC systems have been identified as the primary cause of complaints in the majority of sick buildings. Because these systems play an integral role in creating a livable environment, goals should be established for ventilation, thermal control, indoor air quality and filtration.

*Ventilation Goals* should meet or exceed criteria specified in ASHRAE Standard 62-1989: Ventilation for Acceptable Air Quality ( ASHRAE 1989a). For example, the standard recommends an outside air ventilation rate of 20 cubic feet per minute (cfm) per occupant for office space. In a recent project, the target was set to achieve a design ventilation rate of 40 cfm/occupant (Sterling, 1992). This target assumed that the configuration of the mechanical system results in a ventilation effectiveness of 70 percent. Ventilation effectiveness is the measure of the actual amount of outside air that reaches building occupants. Assuming a ventilation effectiveness of 70 percent at 40 cfm/occupant, the net result would be an actual ventilation rate of 28 cfm/occupant. This rate slightly exceeds the rate recommended by ASHRAE Standard 62-1989. The quality of outside air should also be considered, alongside the quantity of air. If the outside air is determined not to be of acceptable quality for ventilation purposes, designers should employ appropriate air cleaning technologies.

*Thermal goals* should be developed to maintain target ranges for temperature, based on ASHRAE Standard 55-1992: Thermal Environmental Conditions for Human Occupancy (ASHRAE 1992). In addition to temperature, humidity has a significant effect on how livable an environment is perceived by the occupants (Sterling et al., 1985). The humidity target for buildings should be established at 30-60 percent relative humidity. This target is based on recommendations contained in ASHRAE Standard 62-1989.

*Indoor air quality goals* should be established for carbon dioxide and formaldehyde. Carbon dioxide is an index of occupant generated contaminants and formaldehyde is and index of contaminants off-gassed from furniture, fixtures and building materials. Increased outside air ventilation should provide adequate dilution for most other indoor source contaminants. Appropriate goals for carbon dioxide are 600 ppm and for formaldehyde are 0.05 ppm.

*Filtration goals* should be established for filters to achieve a minimum 60 percent dust spot efficiency based on ASHRAE Standard 52-76: Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter (ASHRAE 1976).

*Illumination*





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Goals for illuminance should be established based on the Illuminating Engineers Society (IESNA 1984). These goals are 50-70 footcandles for general office areas and 30-50 footcandles for Video Display Terminal workstations. Targets for spectral quality, day lighting, and task lighting should also be based on tenant use requirements.

*Architecture*

The overall architectural goal should be to meet or exceed the environmental goals wherever possible in the architectural design of the building through careful consideration of: envelope and glazing, configuration and massing, interior planning, materials and acoustics.

*Commissioning*

To ensure that environmental-quality targets have been met, a complete commissioning process of the building environmental and energy systems should also be undertaken upon completion and prior to final acceptance. Ongoing building commissioning should include seasonal monitoring of livability parameters such as ventilation, indoor air quality, temperature, humidity and illumination during the first year of operation along with all energy utilization. The commissioning process should be based on ASHRAE Guideline 1 1989: Guideline for Commissioning of HVAC Systems (ASHRAE 1989b).

## Conclusions

Sick-building syndrome is a pervasive problem occurring primarily in buildings constructed between 1975 and 1989. It can be solved in existing buildings by implementing a phased program of evaluation leading to appropriate renovations or modified operating procedures.

New buildings can be designed and constructed in which occupants will not experience sick-building problems by following a design process that includes an environmental consultant.

References

ASHRAE. 1975. *Energy Conservation in New Building Design*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers.

ASHRAE. 1976. *Standard 52-76. Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers.

ASHRAE. 1989a. *Standard 62-1989: Ventilation for Acceptable Indoor Air Quality*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers.

ASHRAE 1989b. *Guideline 1-1989: Guideline for Commissioning of HVAC Systems*. Atlanta American Society of Heating, Refrigerating and Air Conditioning Engineers.

ASHRAE. 1992. *Standard 55-1992: Thermal Environmental Conditions for Human Occupancy*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers.

Collett, C.W.; Sterling E.M.; Steeves J.F., Weinkam, J.J. 1987 "The Building Performance Database An Analytical Tool for Indoor Air Quality Research." *Indoor Air '87 (Vol 2)*. Siefert, B. (ed). pp. 426-430. Berlin: Institute for Air, Soil and Water Research.

Collett, C.W., Sterling, E.M. 1988a. "Ventilation Inadequacies and the Sick Building Syndrome." *Ventilation 88*. Vincent, J.V. (ed). pp. 367-371. Oxford: Pergamon Press.

Collett, C.W.; Sterling, E.M. 1988b.



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"Ventilation System Retrofits as a Method of Solution for the Sick Building Syndrome." *Present and Future of Indoor Air Quality*. Bieva, C.J. (ed.). pp. 301-308. Amsterdam: Excepta Medica.

Goyer, N., Nguyen, Van Hiep. 1989. *Strategy for Studying Air Quality in Office Buildings*. Montreal: IRSST.

IESNA. 1984. *Lighting Handbook*. Reference Volume. Relationship Among Lighting, Visibility and Task Performance.

Kirkbride, J.; Lee, H.K.; Moore, C. 1990. "Health and Welfare Canada's Experience in Indoor Air Quality Investigation." *Indoor Air '90 (Vol 5)* Walkinshaw, D.S. (ed) pp. 99-106. Ottawa: International Conference on Indoor Air and Climate.

Kleven, S.R.; Sterling, T.D. 1988. "Prevalence of Health and Comfort Complaints of Office Workers: Male and Female Differences." *ASHRAE IAQ 88: The Human Equation—Health and Comfort*. pp. 232-236. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers.

LePatner, B. 1987. "The Expanding Scope of Liability." *Architecture*, pp. 91-92. August.

Levine, K.B.; Collett, C.W.; Sterling, E.M. 1992. "Measurements of $CO_2$ Concentrations to Estimate Outside Air Ventilation Rates." *Proceedings: 85th Annual Meeting: of the Air and Waste Management Association*. Kansas City, June 1992. Pittsburgh: Air and Waste Management Association.

Nathanson, T. 1990. "Building Investigation: An Assessment Strategy." *Indoor Air '90 (Vol 5)*. Walkinshaw, D.S. (ed) pp. 107-112. Ottawa: International Conference on Indoor Air and Climate.

NIOSH. 1989. *Indoor Air Quality: Selected References*. Division of Standards Development and Technology Transfer. Cincinnati: National Institute for Occupational Safety and Health.

Rask, D.R.; Lane, C.A. 1989. "Resolution of the Sick Building Syndrome." *ASHRAE IAQ 89: The Human Equation —Health and Comfort*. pp. 173-177. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers.

Robertson, G. 1988. Source, "Nature and Symptomology of Indoor Air Pollutants." *Indoor and Ambient Air Quality*. Perry, R.; Kirk, P.W. (eds). pp. 311-319. London: Selper Press, Ltd.

Sterling, E., Sterling, T. 1983. "The Impact of Different Ventilation Levels and Fluorescent Lighting Types on Building Illness." *Canadian Journal of Public Health*. Vol. 74, pp. 385-391.

Sterling, E. 1985. "Criteria for Human Exposure to Humidity in Occupied Buildings." *ASHRAE Transactions* 91(1):611-621.

Sterling, E.M. 1992. "Design and Development of an Energy Efficient, Livable Office Building." *Proceedings: First Annual IAQ Conference and Exposition*. pp. 230-234. National Coalition on Indoor Air Quality.

World Health Organization. 1984. *Indoor Air Quality Research*. Euro Reports and Studies 103 Copenhagen: World Health Organization.

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